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THE EVOLUTION OF BOGOSLOF VOLCANO.

BY

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In April of 1907 an expedition started for Alaska from the Massachusetts Institute of Technology to make observations of an unusual sort. Many scientific missions go to remote stations to study eclipses or other stellar happenings, and when a great volcanic eruption or earthquake occurs there is apt to be a rush of geologists, as there was to Mount Pelée in 1902. The Technology Expedition went to the Aleutian Islands in order to make studies of volcanoes without reference to any catastrophe, but the event proved that one of the most wonderful volcanic eruptions ever recorded was there in progress.

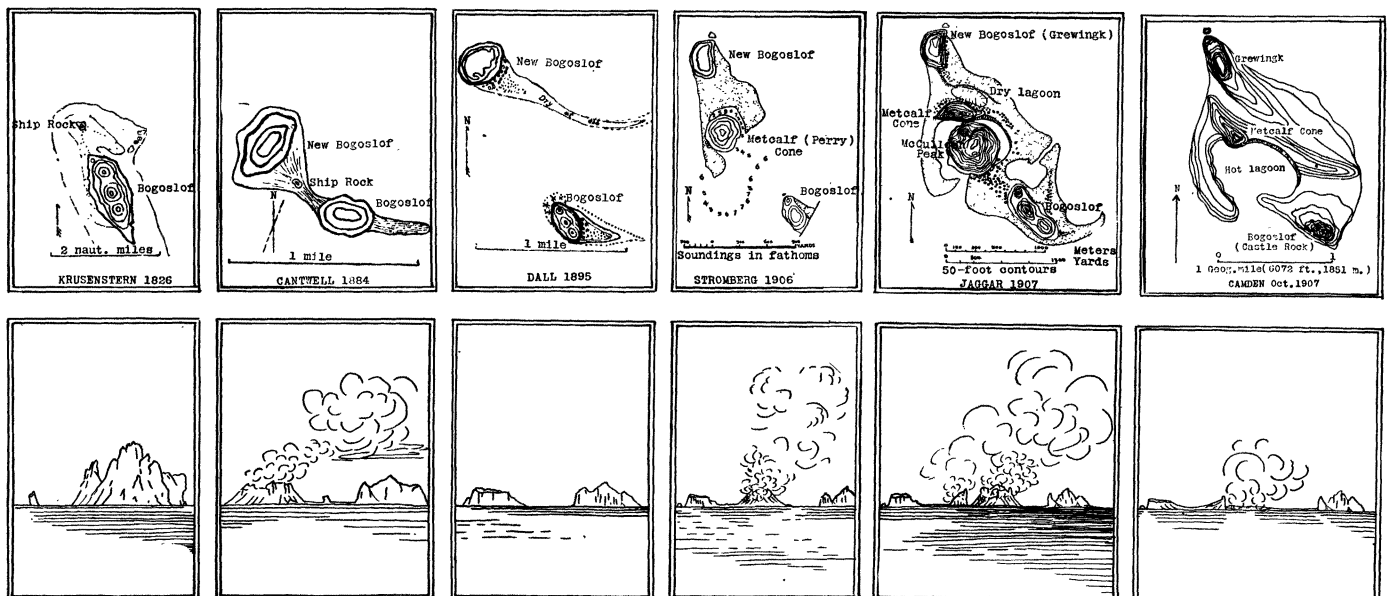
Bogoslof, or Joanna Bogoslova, the Island of John the Theologian, rose from the sea in 1796 with turmoil which gave the natives of nearby Unalaska fright. A companion rock was elevated a mile and a half to the northwest of old Bogoslof in 1883, when the earlier volcano, if a rugged reef of rock may be so named, was wholly extinct and the home of many sea-lions and quick-flying guillemots. The new islet was seen by mariners to be a pile of steaming rocks several hundred feet high; and for more than a decade the boiling continued, the island changing its shape and size, and being intermittently connected with the older excrescence by a gravel isthmus. At the end of the century the new volcano of 1883 was also extinct, and appeared as an isolated flat-topped rock in the sea, separated from Bogoslof by an open channel at least a mile in width and probably ten fathoms deep. Together these rocks have been known to the few ocean traders or revenue officers sailing that way as "Bogoslof." The southern older mass is spoken of as "Castle Rock" and the volcano of 1883 was named after the Russian geographer "Grew-

ingk." Among men of science there has always been some mystery about their origin, for no mention of cone, crater or lava appears in the sea-captains' logs. Explosions there were, and violent ones, for we are told that in 1796 an earthquake shook Unalaska, forty miles away, and there were "fearful noises," and "rocks were thrown from the new volcano as far as Umnak." In 1883 dust and sand fell at Iliuliuk, the native settlement sixty miles to the east.

The accompanying photographs reveal an extraordinary change

MAP SHOWING BOGOSLOF ISLAND.

in these islands. New activity began in March, 1906, and by the midsummer of 1907 two new hills had risen from the sea midway between Bogoslof and Grewingk, continuous land united all into one island, and a hot salt-water lagoon encircled the newer hill which was steaming like a pudding. The history of this transformation has been written in scattered letters and magazine articles by navy and revenue officers, correspondents, geologists, and residents of Unalaska. The following abstracts and quotations show in brief the succession of observations recorded, and the pictures illustrate them.



MAPS AND CORRESPONDING SKETCHES OF BOGOSLOF FROM 1826 TO OCTOBER, 1907.

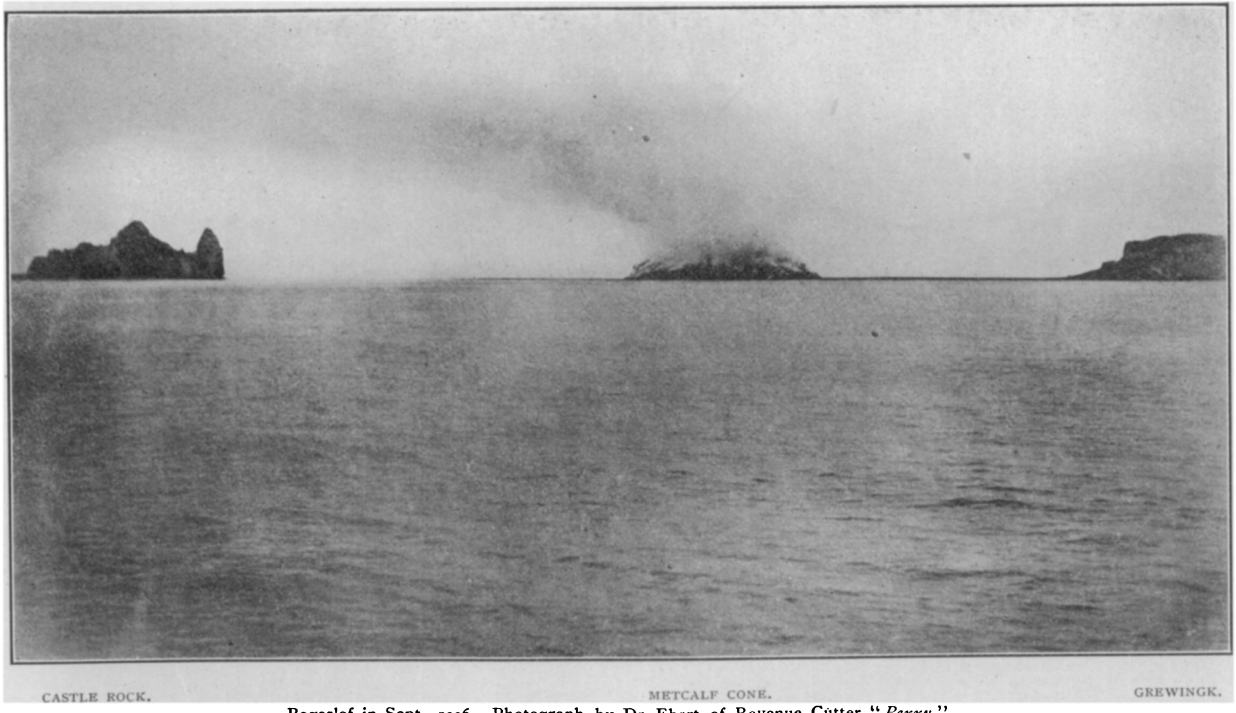
The first three sketches are adapted from Dall 1873, Doty 1884, and Purington 1895; the others from photographs reproduced in this article. (See Merriam, Harriman Alaska Expedition, Vol. 2.)

Lieutenant-Commander Garrett, U. S. N., reported that the *Albatross* reached the Bogoslof Islands May 29, 1906, and found a steaming new cone midway between the two older islands. It was connected with Grewingk by a low flat ridge, but separated by a channel from Castle Rock. This channel was later sounded by officers of the Revenue S. S. *Perry,* and seven fathoms were reported. Garrett wrote: "The new land is conical in appearance, and consists of a mass of eruptive rocks, among which traces of sulphur are plainly visible. It possesses no distinct crater, but numerous vents among the rocks, from which volumes of steam issued." The summit showed a broken horn bending to the northeast, "as though the mass had been forced up through an aperture while in a plastic condition, the sides being quite smooth." This horn proved a remarkable feature, and the key to the whole structure. It has turned out to be a second case of the famous tower of Pelée, which so puzzled the geologists who studied the Martinique eruption. Garrett's suggestion of a rising plastic mass was correct. He proposed for the new hill the name "Metcalf Cone,"* in honour of Secretary Metcalf.

Mr. Robert Dunn visited the new cone in a schooner in July, 1906, and climbed the new peak. He saw that the pudding-like cone had a solid rock core, and the salt-water lagoon which half encircled it on the north had a temperature varying from seventy to ninety degrees. There was no noise. The pinnacle on the summit was like a great parrot's beak, rounded and smooth on the west, but making an overhanging cliff forty feet high on the east. The steam-vents gave temperatures varying from 94° to 212°, and the hottest vent, at the foot of the parrot cliff, was adjacent to rock practically incandescent, for here a piece of paper burst into flame. The top of the spine was about 390 feet above sea-level by pocket barometer.

In the spring of 1907 Captain Dirks, a local trader, brought word that a still newer peak had risen beside Metcalf Cone. The Cutter *McCulloch* visited the scene in July, 1907, and reported that this was indeed true, and, moreover, Metcalf Cone had half collapsed, and the channel between it and Castle Rock was filled up with the new steaming heap, "McCulloch Peak," and a wide stretch of gravel wash. Such was substantially the state of affairs when the Technology Expedition arrived August 7, 1907. A day was spent in exploring, photographing, and collecting specimens. The landing was made in dories in the midst of a herd of roaring sea-lions.

* Later called in press reports "Perry Peak." Commander Garrett's name has precedence.



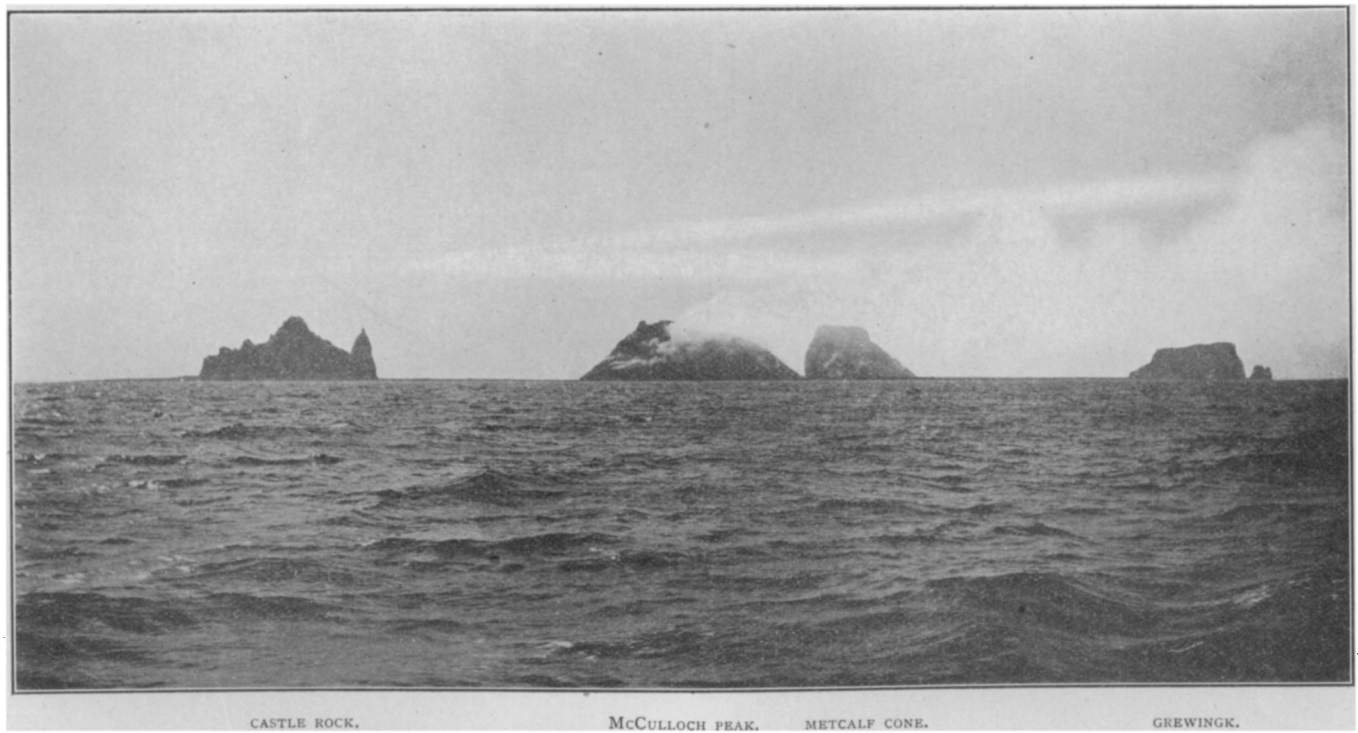
Bogoslof in Sept., 1906. Photograph, by Dr. Ebert, of Revenue Cutter "*Perry*."

These animals when first seen were clustered in great numbers on the sand cusp extending southeast from Castle Rock. Taking alarm they plunged into the sea with much bellowing, and thereafter became divided into separate herds. A shot fired near the precipitous cliffs startled the murres and herring-gulls which nestled there in myriads, and the air was darkened by tens of thousands of them in rapid flight, as they circled far out over the sea and then returned to the cliffs.

The map and photographs show the condition of the island at this time, and it would be difficult to imagine a more extraordinary spectacle. As a land mass above tidewater it was a continuous island about two miles long, with the two new steaming cones in the middle 400 to 500 feet high. Grewingk, flat-topped and cliff-encompassed, guards the north end of the island, while Castle Rock, pinnacled and jagged, rises on the south. The intervening spaces were filled with sand, gravel and volcanic bombs, making wave-washed bars ten or twelve feet above sea-level. It was unbelievable that only sixteen months ago there was nothing there, between the north and south islets, but open water and some ten fathoms of that! In truth it is a land—or an ocean—where the earth is alive, and continents are in the making. "Bogoslof" may, for a time at least, be the name of one island. But what the explorers saw above the sea was only the top of an immense conical mass *beneath* the waves; for Bogoslof on the charts lies forty miles north of the chain of the Aleutian Islands and is just at the one-thousand-fathom line—the new cones are the steaming summit points of a volcano beneath the waves, which is two thousand feet higher than either Vesuvius or Pelée. This lends a new interest to our observations—we are exploring the live crest, equivalent to a crater, of a great submarine heap of lava six thousand feet high, piled above the floor of Bering Sea where the Aleutian mountains fall off to the deep sea.

All the pinnacles of Castle Rock were sharpened between 1906 and 1907—probably by the bombardment of falling stones and sand at the midwinter season when a violent explosion broke Metcalf Cone in twain. There are marks of flood-waves and bombs and pumice on the flats, which give good reason for the belief that the moment which ended the life of Metcalf Cone and began that of McCulloch Peak, in the winter of 1906-7, was explosive, and it will be seen in the sequel that McCulloch suffered a like fate.

A second extraordinary feature of the rocky wall of Castle Rock was a sea-cave at the north end surmounting a rock bench or platform twenty-five feet above the ocean level. This notch and floor



Bogoslof, Aug. 7, 1907, from the east.

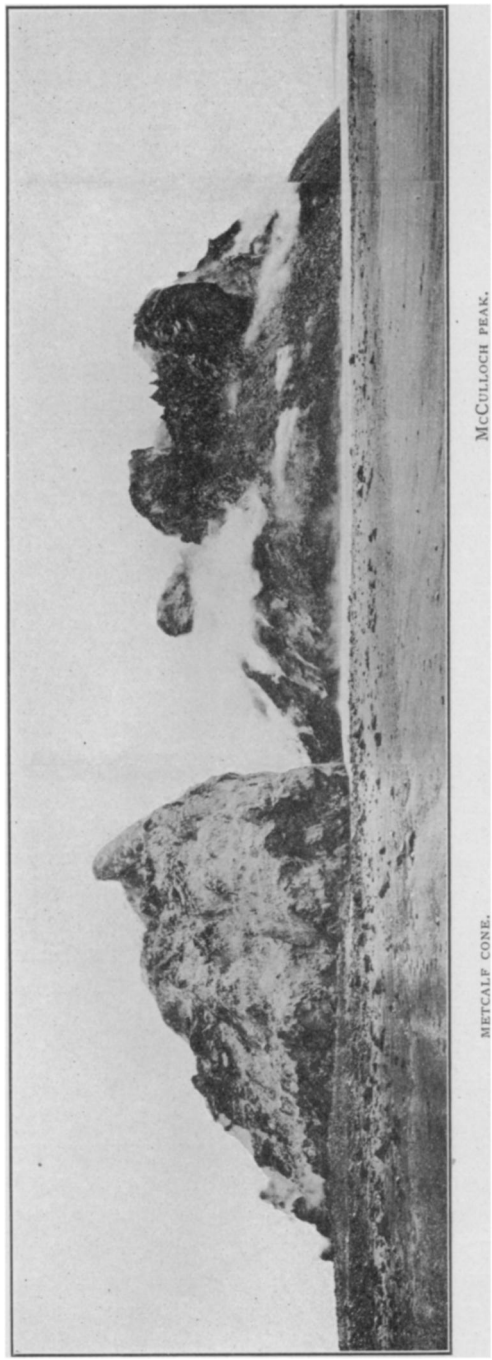
could have been made by only one agent—the surf—now beating the strand at a much lower level. It was evident that there had been an uplift of the land. The question at once arose—How long ago did this elevation of the old island happen? On comparison with photographs of 1906 it is found that the uplift of twenty-five feet has taken place during the last year, for those photographs show the same rock bench and cave *at sea-level.* In other words, old Castle Rock had been rising slowly during the last eight months while McCulloch Peak was heaping itself to much greater heights, one, two, three, and, finally, over four hundred feet, with a base measuring two thousand feet across at the beach level. The massive uplift was in evidence all over the island, even as far north as Grewingk, where it was proved by a high sand beach, and a sea-worn barrier of sand and gravel back of the beach, all at levels well above the action of the waves of to-day. While a half-plastic lava was pushing up rapidly in the middle cone, it appears that the adjacent older hard rock summits of the submarine mountain were slowly heaved up. The meaning of this is that either a larger mass of lava is spreading itself sideways somewhere below, and lifting the volcano on its back, or that the whole sea-floor is slowly warping upward and carrying the chain of islands with it.

Next northwestward from Castle Rock, connected with it by a broad gravel ridge flanked by sea beaches and indented by a lagoon on the east, came McCulloch Peak, the most sensational object of recent development. Of rounded cone shape, nearly 450 feet high, this hill appeared at first sight like a steaming heap of bowlders. The top in profile was flattish, but lumpy, made of hard rock, and without any crater. There were rocky crags at the core and summit of the mass, with slide rock about its foot-slopes fed by the tumble from the rising cliffs above. Not that the tumbling or the rising could be seen—it was too slow for that. All was deathly quiet—but dangerous-looking.

Circular in plan, this peculiar volcano was nearly enclosed by a sickle-shaped lagoon of salt water. The water lapped the slide-rock slopes directly, without any intervening beach, the tumble of fragments under water was stained bright orange, and all the water was turbid and hot, steaming silently, at a temperature of about 90 degrees. The peak itself was steaming in places from rifts in the hot rock, and the larger vents showed yellow sulphur coatings. The steam vents were not very numerous, but made a great show owing to the wafting of the vapour by the wind. The vapour was pure white and there was at this time no evidence of explosive

violence or hissing. The rock is hornblende-pyroxene andesite, a refractory lava.

At two places very steep slopes and even jutting rock were seen at the base of the hill, where the slide material was thin over the lava beneath. Generally the core was masked by the slide-rock and the latter was straight and pronounced in the profile of the hill, giving it the cone outline. Above was bedrock and this projected in extraordinary lumps or bulbs. If the foot-slopes could have been washed away the rock core would have looked like a gigantic potato lifting its lumpy protuberances above the waves. Three very large excrescences protruded on the north and northwest, overhanging the lagoon, and one ragged dome could indistinctly be seen on the summit of the hill in the steam.



Protuberances of McCulloch Peak, the Spine and Carapace of Metcalf Cone, and the Hot Lagoon, looking southeast, Aug. 7, 1907.

Only at one point was the slope accessible without wading or swimming and to climb the peak here was impracticable, the slide stones being too loose and the hot rock slope above too steep. On the outer borders of the sickle lagoon were gravel reaches which enclosed it from the sea, as shown on the map.

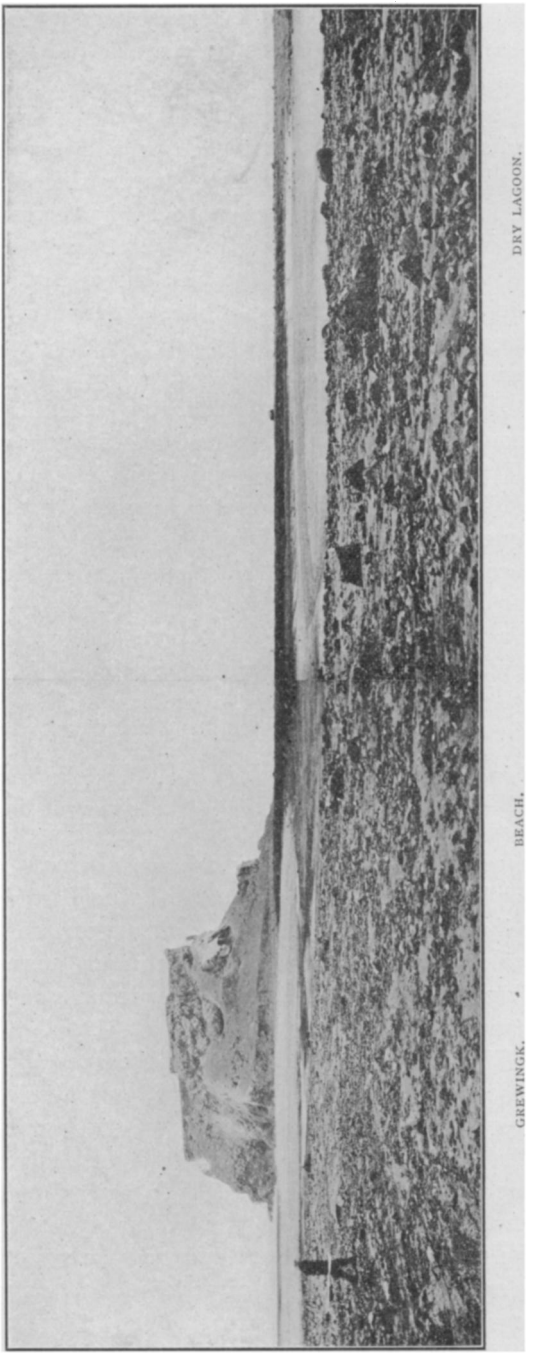
Metcalf Cone, now a half-cone, was adjacent to the base of McCulloch Peak on the north, and it presented on the McCulloch side a sheer face of rock descending to the waters of the hot lagoon. Seen from east or west the profile of Metcalf was like what McCulloch would be if chopped in two with the northern half remaining, and its history corresponds with this description, for it was the preceding year a complete cone of about the same size as McCulloch. McCulloch Cone had grown from the midst of the ruins of the destroyed half of Metcalf. On the upright half of the ruin, the "parrot's beak" was still preserved on the highest point of the summit at the top of the cliff-wall, and its extension downward in the core of the cone was shown in cross-section to the very base, thanks to the freak of nature that had split the cone in two along an up-and-down plane as though for the express benefit of the visiting geologist.

The splitting of the cone in two has left the central spine wonderfully revealed. The middle portion of the wall showed the outline of a spire of about the proportions of a blunted fish-horn or inverted cornucopia, extending from sea-level to the beak on top. The base of the spire was about 360 feet across, and the summit was one third as wide and 400 feet high, rounded towards the west both in plan and profile like a beak. The resemblance to a beak was increased by regular markings on the rounded surface as though the horn had been shoved up at intervals. Apparently it had been squeezed out, like paste from a tube, in a semi-plastic condition, had gradually shaped a roundish cavity for itself in the lava about it, and like a great worm rising from its burrow had turned its head toward the east. Here it broke away through lack of support, making on that side a long slide of fragments surmounted by a ragged overhanging precipice forty feet high.

Under the spine on the north side of the summit of Metcalf Cone there is a turtle-back half-dome surface, ragged and broken on the east just as the spine is, and like the spine curving down to the west beneath a mantling mass of rough lava. The spine, in fact, is a part, the middle part, of a great column of lava enclosed in a hardened carapace or shell. This column rose through a crusty mass of its own substance and became overturned toward the east. The spine was the top of the last central remnant of the fluid lava, which made

one final upward push. Seen from the north, in the direction of Grewingk, the spine resembled a great shark's fin on top of the hill—and such resemblance was also commented on by geologists with reference to the famous spine or tower of Pelée, which was another example of the same process—a stiff and unwieldy lava rising in a nearly solid condition so that it was never permitted to flow downward in a stream like the lavas of the better known volcanoes in Italy and the Hawaiian Islands.

North of Metcalf Cone the site of the lagoon which had been deep and hot in 1906 was in 1907 high and dry. Beyond it a high gravel reach extended a fifth of a mile to Grewingk, a square rocky table 250 feet high, surrounded by cliffs, and highest at the northeast corner. Like Castle



Grewingk, elevated beach and dry lagoon, looking north, Aug. 7, 1907.

Rock these cliffs were the home of innumerable sea-birds. Indeed these hardy birds seem to luxuriate in the volcanic warmth—perhaps it aids the hatching of their eggs, for even on the venomous-looking lava projections of McCulloch Peak, in the midst of steam and heat and sulphur, the birds crowded, as elsewhere, and laid their eggs in the hollows of the rocks and there reared their chicks. Adults, chicks, and eggs occupied every habitable cranny of all the cliffs on the island. Lively the place was in every sense, the hot earth alive, heaving and heaping, the sea alive, currents, surf, and warm lagoons; the shore alive with the hundreds of immense clumsy leviathans, bulls, cows, and pups; and, finally, the cliffs alive with their teeming bird-life.

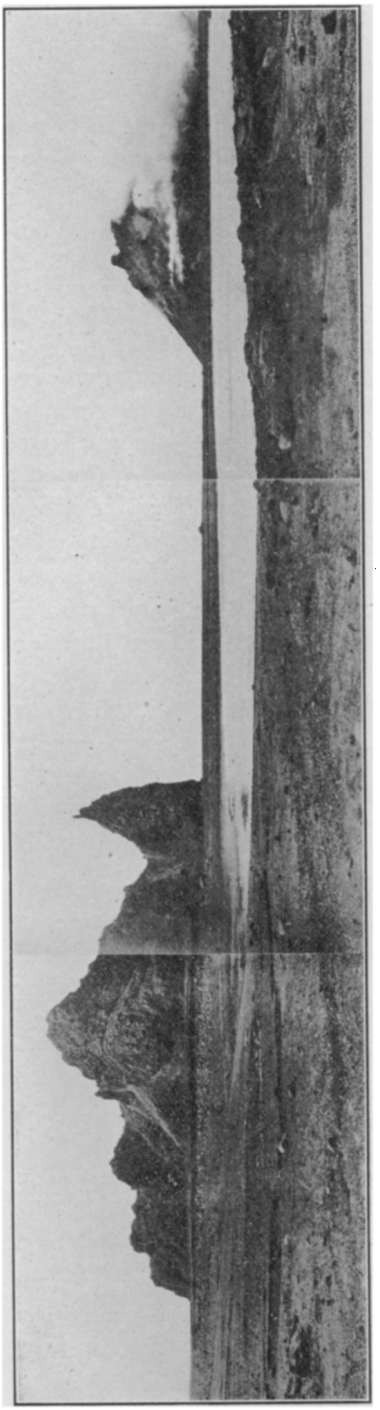
Dr. Van Dyke, naturalist to the expedition, reported finding on Bogoslof beetles, flies, ticks, mites, sea-weeds, and even land grasses. All this combination of activities, with man added, clambering, paddling his frail bark and poking his nose inquiringly into every corner with a view to conscious ratiocination, made of Bogoslof a place for philosophical reflection. Surely here, if anywhere in the world, we were in at the beginning of things, and could take a peep at a continent in embryo, and see land grow fast enough to show results within the limits of human time.

Truly it showed results, and that right soon. On September first, twenty-four days after the Technology Expedition left Bogoslof, the natives, traders, and revenue officers who live at Iliuliuk saw toward the west a dense black cloud rising and the air was full of sulphur fumes. About five o'clock in the afternoon ash and sand began to fall, followed by rain and distant rumbling. A quarter-inch layer from this snowstorm of sand settled on roofs and shipping and grassy landscape, making all appear wan and drooping with a monotonous gray mantle. There were at first many rumours attributing this ash-fall to different volcanoes, for there are over fifty known in the Aleutians.

The Cutter *McCulloch* settled the question in October by visiting Bogoslof and finding McCulloch Peak absolutely gone, a steaming lagoon in its place, and the rest of the island piled high with fallen débris. The map and photograph here shown were made at the time of this visit. The half of Metcalf Cone was still "standing in grim silence as a headstone at the grave of the departed peak." The north slope of Metcalf showed the smooth cone curve, concave in profile upward, so characteristic of cinder-cones like Fuji or Vesuvius, and this marked for Bogoslof one more step in the cone-building process. The pure curve was made by new-fallen frag-

ments added to the lava cone. Lieutenant Camden of the cutter reported that "Castle Rock, on account of its precipitous walls, had no considerable depth of the lava dust deposited on it, and, consequently, its form remains unaltered, but its colour is like Portland cement. At intervals a mass of this lava dust will be jarred or blown from its bed, high up among the rocks, and come tearing down the cliffs to the beach, raising a cloud of dust with it that is almost identical in appearance with the vapour rising near by, and leaving its starting point bare and white in contrast with the colour of the undisturbed dust covering the adjacent rocks." The lagoon where McCulloch Peak had been was a deep bay, open to the west, half a mile in diameter, with steam rising in considerable quantities from the surface of the water, and on its north shore the bank was precipitous and estimated to be 100 feet high.

By analogy with what is known of such volcanoes it is easy to imagine the probable sequence of events toward the end of August which resulted in the demolition of McCulloch Peak. First there came increased pressure of steam through the fissures of the lava, and especially through a main vent somewhere in the centre. On the afternoon of September first explosions from the deep region discharged rock dust and



CASTLE ROCK AND McCULLOCH PEAK, LOOKING EAST, AUG. 7, 1907.
Note the elevated sea-beach along the base of Castle Rock and the sharpened pinnacle.

steam through this vent, and great columns were sent skyward with "cauliflower" whirls charged with solid matter and full of lightnings. At about 5 P. M. this great jet of superheated steam rose perhaps three or four miles vertically and the westerly winds distributed the finer sand and dust, while the heavier rocks fell back on Bogoslof. The explosion undermined the lava of McCulloch Cone, enlarged the vents until the partitions fell in, and the hill crumbled beneath the waters of the lagoon, the cold sea-water quenching and crusting what lavas it reached. Atmospheric disturbances produced local thunderstorms and these brought the eruption to a close.

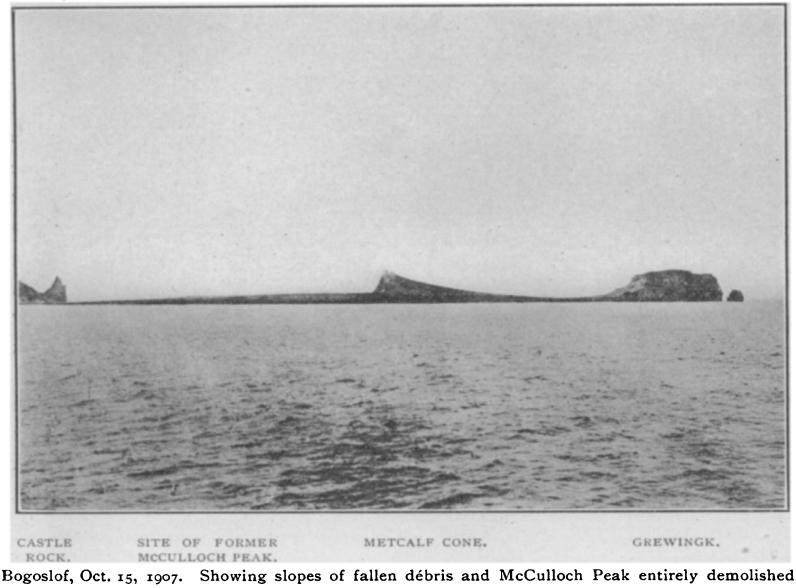
A review of the previous happenings, the rise of Metcalf Cone in 1906, its destruction in the winter of 1906-7, and the welling up of the lava of McCulloch Peak immediately thereafter, suggests that the two cones were the products of repeated stages in the same process, and that the explosion of September, 1907, was the equivalent for McCulloch Peak of what had destroyed Metcalf Cone. If the dates of the several events are examined in the light of this suggestion, there seems to be a rhythmic process shown, thus:

Metcalf Cone rose March, 1906.
Metcalf Cone, 400 feet high, 2,000 feet across.
Metcalf Cone destroyed about November-December, 1906.
Life of Metcalf Cone, 10 months.
McCulloch Cone rose about December, 1906.
McCulloch Cone 450 feet high, 2,000 feet across.
McCulloch Cone destroyed September 1, 1907.
Life of McCulloch Cone, about 10 months.

The mechanism of the process by which these cones rose above the waves and formed protuberances and spines may be imagined somewhat as follows: From a deep fissure in the crust of the earth, under the sea, hard, hot lavas have for many centuries been welling up and crusting over. In contact with cold sea-water, which breaks through fissures to the hot slag, and presses in on it from all sides with mighty pressure, these lavas explode violently and maintain explosion openings, now here, now there, but in general through the top of the heap. Gradually by lava and explosion a great submarine volcano has been built six thousand feet high above the floor of the sea.

Since the latter end of the eighteenth century this lava heap has reared its summit above the waves. Still at certain intervals the lavas creep upward and rend apart the fissure which first gave vent to Old Bogoslof in 1796, and each time explosion plays its part,

perhaps by sea-water making contact with slag, perhaps by force of vapours contained at high pressure in the lava. For a single eruption, like the growth of Metcalf Cone, the dome and spines which rose above the sea were together the top of a body of hard lava rising within an earlier solidified crust of its own substance. The central streams wore cylindrical cavities for themselves in the harder material, moved up and out, bent over, and broke off gradually on the sides away from the bends, leaving rounded surfaces on one side and steep ragged faces on the other. These made the visible pro-



Bogoslof, Oct. 15, 1907. Showing slopes of fallen débris and McCulloch Peak entirely demolished.

tuberances and carapaces. Cooling and solidifying went on throughout the mass, until there was left only a small central pencil of lava pushing up in the middle, most solid and narrowest at the top, progressively wider and more fluid downward within the cone. This made the spine as in Metcalf Cone.

It is a question of some interest whether continued pushing from below did not open ways by which ocean water entered, made steam explosions and so automatically the rising lava accomplished the destruction of what it had built. If this explanation be accepted, then the repeated sequence of events and the like dimensions and life periods of Metcalf and McCulloch Cones are easily accounted for. A single lava column was rising at a uniform rate: it built

Metcalf, became self-obstructed, opened fissures to sea-water and exploded; built McCulloch, became self-obstructed, opened fissures to sea-water and exploded. Did a third cone rise on the spot during the winter of 1907-8 only to be demolished in another ten months or about June, 1908?

The remarkable processes of volcanism and earth movement in the Aleutian Islands deserve continuous, close study from an observatory erected for the purpose on Unalaska. The winter of 1907-8 has been wasted—lost to science, because no observers were stationed there. There are few observatories for the instrumental study of our own earth anywhere, though there are hundreds for the study of the stars. The Geological Society of America at its winter meeting of 1907-8, held at Albuquerque, passed a resolution to the effect that the Society strongly recommends to the several North American governments *and to private enterprise* the establishment of volcano and earthquake observatories. The motives stated are that we possess in the Cordilleran Belt, Alaska, the Philippines, the Hawaiian Islands, Porto Rico, and the Canal Zone, a wide field for investigation of active volcanoes and earth movements; that geological science needs permanent record, made in the field, of physical phenomena accompanying earthquakes and eruptions both before and after the event; and that such record has direct bearing on prediction, and on protection of life and property.

The writer has italicized the words "and to private enterprise," in order to draw attention to a broad unexplored field of research that opens many possibilities to men of wealth, yachtsmen, and to institutions of learning. Exploration, experiment, extended local observation, and permanent observatories are all needed for accumulating data concerning this old earth, which is pushing up and down its shore lines in a hundred places not yet explored, but known to geologists, and building other Bogoslofs.